Reducing inflow to stormwater sewers by the use of domestic rainwater harvesting tanks

Réduire les entrées d'eaux pluviales dans les collecteurs par le développement de l'utilisation de réservoirs individuels d'eaux pluviales

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RÉSUMÉ

Cet article présente une analyse de la performance des systèmes de récupération des eaux de pluie pour une utilisation domestique afin d'évaluer les économies d'eau que l'on peut atteindre et la réduction des volumes d'eau rejetés dans les collecteurs d'eaux pluviales. Une méthodologie sans dimension basée sur les simulations d'équilibre de l'eau à l'échelle temporelle quotidienne a été appliquée à des séries de pluies à Oslo (Norvège), en tenant compte des scénarios historiques et futurs caractérisés par le changement climatique dans la pluviométrie. Les résultats obtenus montrent des avantages importants en matière d'économie d'eau pour des bassins de retenue relativement petits avec des bénéfices marginaux réduits lorsque la taille du bassin augmente. L'utilisation du bassin de retenue peut également entraîner une réduction considérable du volume d'eau rejeté dans le système de collecteur d'eaux pluviales. Une performance presque identique du système a été obtenue avec les différents scénarios de pluie, confirmant ainsi l'efficacité du système également dans des conditions de climat changeantes. Les résultats ouvrent la voie vers des recherches pour tester les systèmes DRWH à des délais de résolution plus élevés pour examiner les avantages découlant de la réduction des taux de débit de pointe dans les collecteurs.

ABSTRACT

The paper presents an analysis of the performance of rain water harvesting systems for domestic use to evaluate the obtainable water saving and the reduction of water volumes discharged to storm water sewers. A dimensionless methodology based on the water balance simulations at daily temporal scale was applied to rainfall series in Oslo (Norway), taking into account historical and future scenarios characterised by climate change in rainfall patterns. The obtained results show high water saving benefits also for relatively small storage tanks with reduced marginal benefits as the tank size increases. Also, the use of the storage tank can provide a significant reduction of water volume discharged to the storm water sewer system. An almost identical performance of the system was obtained with the different rainfall scenarios, confirming the efficiency of the system also under climate changing conditions. Results open the research discussion to test the DRWH systems at higher resolution time scales to investigate the benefits deriving from the reduction of peak flow rates in sewers.

KEYWORDS

Climate change, Rainwater tanks, Overflow volume reduction, Water saving

INTRODUCTION

In many parts of the world, domestic rainwater harvesting (DRWH) is considered an important option to cope with restricted availability of freshwater. DRWH primarily consists of the small-scale concentration, collection, storage and subsequent use of rain water runoff coming from rooftops, courtyards and other surfaces for domestic use. Collected rain water can reduce the demand on potable water supplies for several less quality-demanding water uses such as toilet flushing, terrace cleaning or private garden watering.

At the same time, rain water harvesting systems can improve the retention capacity of urban catchments as the basic prerogative of such systems is the setup of storage facilities to retain rainfall volumes temporarily. Tanks, cisterns and other storage facilities can assume an important role to reduce runoff and storm water flows in drainage systems and then to decrease the frequency of flooding in urban areas and the discharges to receiving water bodies.

There is a large literature concerning methodologies to estimate water saving performance of rain water harvesting systems with lots of scientific documents basically regarding countries coping with water scarcity problems. Approaches mainly include the use of harvested rain water for the toilet flushing and the evaluation of the rain water tank size as a function of the desired level of water saving performance (i.e. reduction of potable water use in houses). Results (Fewkes and Butler, 2000; Lee et al., 2000; Villarreal and Dixon, 2005; Ghisi and Ferreira, 2007; Guo and Baetz, 2007) indicate that the tank size cannot be standardized, being markedly influenced by site-specific variables such as local rainfall, roof area, potable water demand and number of people in the household (Mwenge Kahinda et al., 2007; Eroksuz and Rahman, 2010).

Although rainwater harvesting has been historically used in areas where water supply was limited by climate or infrastructure issues, more recently the practice of rainwater harvesting has been undertaken also in humid and well-developed regions to mitigate the environmental impact on fresh water sources and also to reduce storm water runoff volumes, manage urban flood risk and decrease urban waterlogging problems (Fletcher et al., 2007; Mitchell et al., 2007; Burns et al., 2010; Matthew and William, 2010; Petrucci et al., 2012; Zhang et al., 2012). In particular, the retention performance of domestic rainwater tanks has started to be investigated in order to evaluate the benefits of using such systems as source control method to reduce storm water flows.

In this context, some authors (Coombes and Barry, 2008; Hanson et al., 2009; Palla et al., 2011, Burns et al., 2012; Brodie, 2012) have started exploring the retention performance of rain water tanks at different spatial and temporal scales by simulating water balances with the use of behavioural models. Tsai and Chiu (2012) investigated the performance of rainwater harvesting systems in New Taipei City. Results show that, using different tank sizes, the system can achieve a 26.5%-100% runoff volume and a 15%-100% peak flow reductions. Zhang et al. (2012) estimated the potential of rainwater harvesting and its role in reducing runoff volume to mitigate urban waterlogging problems in residential district in Nanjing, China. The results showed that a great potential for exploitation of rainwater harvesting from building’s rooftops and other underlying surfaces is possible with reduction from 14% to 58% of runoff volume.

However, little research has been found on the long term retention benefits of DRWH systems with specific reference to the detrimental impact of climate changes on such systems.

In this paper, the performance of DRWH systems is analysed as function of the size of the DRWH tank under various rainfall conditions representative of different climate change scenarios. A dimensionless approach based on the results of water balance simulations at daily temporal scale is applied to determine both the obtainable water saving and the reduction of inflow volumes to storm water sewers. Specifically, the sizing of rainwater harvesting systems is investigated as a function of two dimensionless parameters: the demand fraction and the modified storage fraction. The methodology is applied to daily rainfall series in Oslo (Norway), taking into account present and future scenarios characterised by climate change in rainfall patterns.

The concept and testing case study presented in this paper allow exploring the efficiency of the traditional DRWH not only to increase domestic water saving, but also to reduce the inflow discharge to storm water sewers as an option to increase urban resilience to climate change impacts.

1 METHODOLOGY

1.1 Water balance equations

The typical scheme of a domestic rainwater harvesting system is based on the collection of rain waters coming from the building roof (and/or other surfaces) and on their temporary storage within a rainwater tank (Figure 1). Under this scheme, demand for water uses in the house which are compatible with rainwater quality is satisfied primarily by water accumulated into the storage tank and only then, by water from the mains supply.

In the present research, the demand was limited to the toilet flushing use (that represents an important part of water consumptions in houses) and it was assumed to occur at a constant daily rate since toilet usage does not show large daily variability (Fewkes, 2000). For such a use, only basic water treatment (i.e. filtration and chlorination) should be accomplished and storage tanks with limited size would be required since the daily toilet water demand is relatively constant also during the year.

The evaluation of water saving obtained with such a DRWH scheme was carried out by simulating water balances with a behavioural model based on a yield-after-spillage (YAS) algorithm as tank release rule. The YAS operating rule is translated into equations as (Jenkins et al., 1978):

$$Q_D(t) = \max \begin{cases} V(t-1) + A \cdot R(t) - S \\ 0 \end{cases}$$

$$Y(t) = \min \begin{cases} D(t) \\ V(t-1) \end{cases} \qquad (1)$$

$$V(t) = \min \begin{cases} V(t-1) + A \cdot R(t) - Y(t) \\ S - Y(t) \end{cases}$$

where Q_D (m^3) is the volume discharged as overflow from the storage tank, V (m^3) is the volume in store, R (m) is the rainfall, Y (m^3) is the yield from the storage tank, D (m^3) is the water demand, t is the time interval, A and S are the effective (net) roof area (m^2) and the tank storage capacity (m^3), respectively (Figure 1).

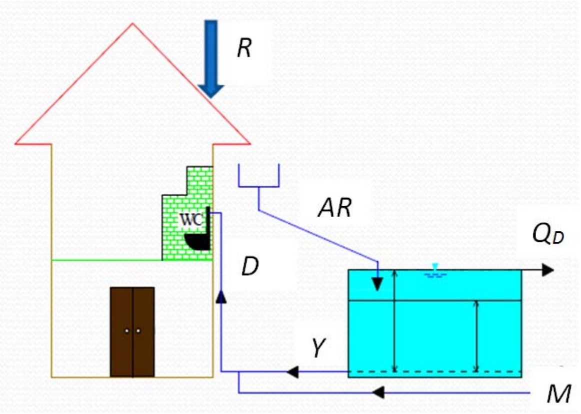

Figure 1. DRWH system scheme

To evaluate the DRWH system behaviour, Equations (1) were applied using the daily time step resolution, as recommended in the literature (Fewkes and Butler, 2000). Simulations with larger time steps (monthly) clearly result in a more economic data set but they are too coarse and would provide inaccurate prediction of system retention performance. On the other hand, smaller time steps (typically hourly) would require to treat more extended set of rain data and also to know detailed information on the domestic demand use patterns.

1.2 Dimensionless parameters and system performance

The performance of the DRWH system are affected by several variables. Along with the characteristics of the installation (i.e. rainwater tank storage capacity), of the household consumption (water demand patterns) and of the building (effective rooftop area), the rainfall characteristics of the site (such as average precipitation, dry weather period) result crucial to evaluate the obtainable water saving and the reduction of inflow to sewers.

To consider different combinations of demand, storage capacity, roof area and precipitation, a dimensionless approach has been used and the following dimensionless ratios, namely demand fraction and modified storage fraction (Campisano and Modica, 2012a; 2012b) were taken into account:

$$d = \frac{D}{A \cdot R} \tag{2}$$

$$s_m = \frac{S}{D \cdot n_D / n_R} \tag{3}$$

assuming D and R as average daily values. Chosen parameters allow improved description of the character of the intra-annual rainfall patterns, since n_D and n_R are the number of dry and rainy days in the year, respectively. Then, the ratio n_D/n_R is the average dry period (days) in the year per each rainy day; accordingly, parameter s_m allows to relate the tank storage capacity to the water demand during the average dry period. It should be emphasized that s_m results of easy calculation since values of n_D and n_R are normally provided as basic data of rainfall stations.

The performance of the DRWH system was evaluated in terms of both obtainable water saving and overflows from the tank (as a measure of water volumes directed to the storm water sewer). In particular, the daily time step simulation allowed to evaluate water saving W_S (%) and overflow discharge O_V (%) as:

$$W_s = \frac{\sum Y}{\sum D} \cdot 100 = \left(1 - \frac{\sum M}{\sum D}\right) \cdot 100 \tag{4}$$

$$O_v = \frac{\sum Q_D}{\sum A \cdot R} \cdot 100 \tag{5}$$

where Y is the volume yielded from the storage tank, M is the volume supplied by the mains, Q_D is the volume discharged as overflow from the storage tank, and where the sums are extended to each year of the water balance simulation. Equation (4) shows that water saving assumes the value 0% when only water from mains is used ($M = D$) and the value 100% when only stored rainwater is used ($M = 0$). Equation (5) shows overflows increasing to 100% for Q_D close to AR (typical of very small tanks and/or toilet demands).

Simulations were run using a in-house software code and results were statistically elaborated by a frequency analysis. In detail, yearly values of W_s and O_v characterised by prefixed levels of exceedance frequency f were determined. The frequency levels 50%, 75% and 90% were taken into account for the evaluations.

1.3 Impact of climate change

The impact of climate change on the system can be addressed taking into account changes in quantity and quality (patterns) of the precipitation. In particular, in this paper the impact of climate changes on the performance of DRWH systems was evaluated in terms of effects on both water saving and reduction of volumes discharged to the storm water sewer.

To this aim, observed rainfall series and projected rainfall scenario series provided by Regional Climate Models (RCMs) were used in order to compare a historical scenario to two future scenarios characterised by climate changes at mid-term and long-term projection, respectively.

Appropriate length of daily rainfall time series have to be chosen (at least 30 years) to guarantee statistical significance of results and to allow a suitable assessment of the system performance also considering the influence of inter-annual variability on the estimation of water saving and overflow discharge (Palla et al., 2011).

The observed and projected rainfall time series were provided to the model as inputs for the historical and future scenarios, respectively. Water saving and overflow discharge for each simulation scenario were evaluated and compared to assess the impact of precipitation changes on the DRWH system performance.

2 THE CASE STUDY

Flooding and sewer overflows are major problems in Norwegian cities. Then, the use of domestic tanks to collect and use precipitation in buildings can significantly increase the urban catchment retention and reduce flows to storm water sewers. Although several technical guidelines of handling surface storm water are available in Norway (e.g. Lindholm et al. 2008; Oslo-VAV, 2011; Hafskjold et al., 2012), practice is not common in existing building areas. To reduce sewer flow peaks in future, some municipalities are evaluating to disconnect stormwater from private building roof areas to the public sewer systems that may enforce building owners to retain or to infiltrate stormwater in private areas. At present there is neither clear legislation nor scientific assessment supporting municipalities to implement such actions. For such reasons a case study in Oslo, Norway was identified in this study to test the benefits of DRWH tanks not only as alternative source of water for domestic use, but also as control option to decrease discharge of volumes to storm water sewer systems.

Oslo climate is typically humid continental with mild to warm summers with average high temperatures of 20–22 °C whereas winters are cold and snowy with temperatures between −7 °C up to −1 °C. Average annual precipitation is about 760 mm with moderate rainfall throughout the year. Snowfall can occur from November to April, but snow accumulation occurs mainly from January through March.

Since 1960s the Norwegian Meteorological Institute (NMI) has been collaborating with municipalities on collecting and managing precipitation data (Kjensli et al. 2009). The meteorological station of Blindern has operated since 1937 with availability of over 73 years of continuous observation data concerning precipitation (including snow), air temperature and evaporation. It has been used as a central station to analyse climate change in Oslo and it has the most available projected scenarios with different temporal and spatial resolutions.

Estimates of future climate change are based on standard scenarios of GreenHouse Gases emissions described in the IPCC'S Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000). 40 SRES scenarios are suggested by IPCC report, which are divided into 4 broad families of emissions scenarios (A1, A2, B1, B2) depending on the adopted hypothesis concerning economic, social, and environmental sustainability.

Among SRES scenarios suggested by IPCC, the NMI considered two high gas emission scenarios (IS92A and A2) to account for critical climate change projections. In particular, the application of the RCM model HIRHAM allowed the NMI to analyze daily precipitation values provided by such scenarios with a 55x55 km^2 grid output (Skaugen, 2004).

Then, the following three scenarios were considered in the present investigation to determine the input precipitation data for the water balance model to analyse the performance of DRWH systems under different climatic conditions:

1. control scenario (for period 1961-1990);
2. mid-term climate change scenario, IS92A (relative to period 2013-2042);
3. long-term climate change scenario, A2 (relative to period 2071-2100).

Scenario 1 was used as reference for the past, while scenarios 2 and 3 were chosen as representative of mid-term and long-term projections. All the three scenarios cover a 30-years period and for each scenario, rainfall data are available with daily resolution.

Table 1 summarizes the main rainfall statistics of the considered rainfall time series (the average yearly number of rainy days, the ratio n_D/n_R, the mean value of rainfall in a year, the standard deviation and the coefficient of variation). The table shows the way climate change influences the rainfall time series with slightly increased average yearly precipitation for the long-term projection scenario in comparison to the control scenario. Also, climate change effects are visible with the reduction of the rainfall event frequency (in terms of number of rainy days or n_D/n_R). Such variations result more evident from the analysis of extreme events at the daily time scale.

	Average nbr. of rainy days	**n_D/n_R**	**R (mm)**	**Standard deviation (mm)**	**Cv**
Control scenario	114	2,27	762,20	134,49	0,18
Mid-term scenario IS92A	106	2,49	760,96	106,28	0,14
Long-term scenario A2	104	2,56	776,46	153,21	0,20

Table 1. Statistical characteristics of the considered rainfall time series

3 RESULTS AND DISCUSSION

Results of simulations are presented by means of dimensionless graphs which allow to evaluate, in correspondence of prefixed exceedance frequencies, water savings W_S and overflow discharges O_v as function of parameters *d* and s_m. All the simulations were run for demand fraction values *d* of 0.2, 0.5, 1.0 and 2.0 and for values of the modified storage fraction s_m in the range 0.05 ÷ 20.0. Selected ranges allow to consider values of water demand, storage capacity, roof area and precipitation characteristics useful for the practical applications. Results of the simulations concerning the control scenario (1961-1990) are separately reported for W_S and O_v in the graphs of Figures 2 and 3, respectively for the selected values of the demand fraction *d*.

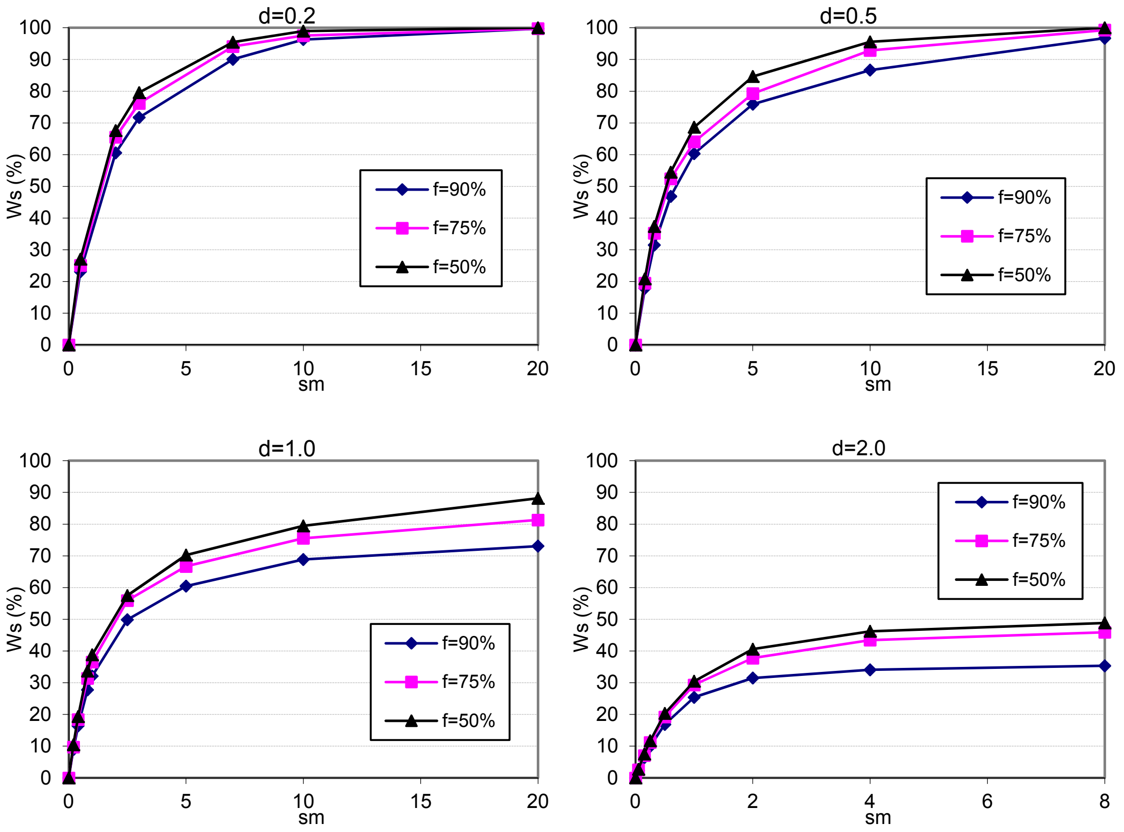

Figure 2. W_s values as function of *d* and s_m for the control scenario (1961-1990)

In particular, the curves plotted in the four graphs of Figure 2 show, as expected, that values of W_S increase as s_m increases (i.e. as the storage tank capacity increases and as the daily water demand decreases). Also, as expected, the figure shows that the values of water saving tend to decrease as *d* increases (i.e. as the daily water demand for toilet flushing increases and as the effective area of the roof decreases). For instance, in half of the cases (f = 50%), in correspondence of s_m = 5 (which means to set up a tank with size 5 times the daily water demand), values of W_S decrease from about 85% to about 45%, when the house demand fraction *d* increases from d = 0.5 to d =2.0.

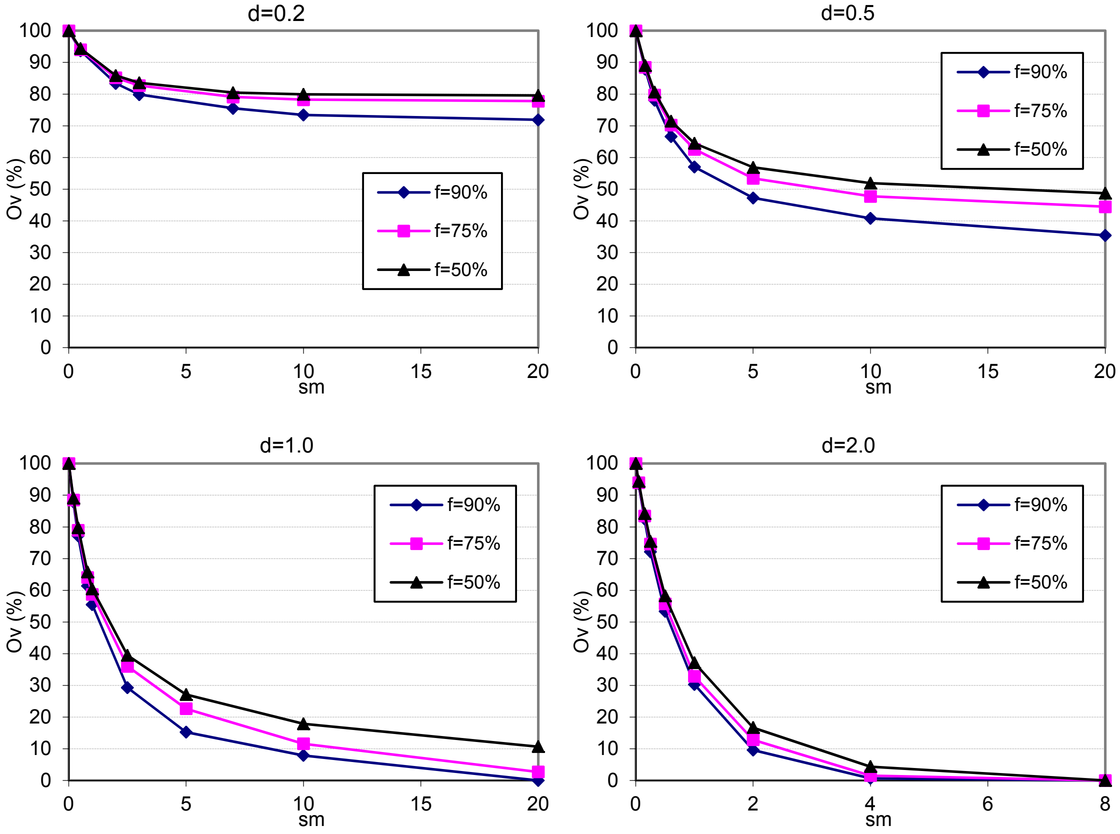

Figure 3. O_v values as function of d and s_m for the control scenario (1961-1990)

As tank overflows (and then volumes to the storm water sewer) are examined, curves reported in the graphs of Figure 3 show decreasing values of O_v as the storage fraction s_m increases, globally pointing out the substantial reduction of flow volumes adducted to the storm water system as the tank size increases and as the house rainwater demand increases. As an example, values of O_V decrease from about 56% to about 3% in half of the cases (f = 50%) in correspondence of a value of s_m equal to 5 when increasing *d* from 0.5 to 2.0.

Finally, the graphs of the figure 3 show that all curves tend to flatten as s_m increases, clearly evidencing that the adoption of very high-storage tanks does not provide significant marginal benefits and pointing out the need of a cost-benefit systems analysis to address the optimal tank sizing.

Results concerning simulations of projection scenarios IS92A (mid-term projection) and A2 (long-term projection) are presented in Figures 4 and 5 respectively.

The figures show that curves obtained for the two projection scenarios result close to those presented for the control scenario. Accordingly, previous remarks concerning graphs of Figure 3 remain valid also for graphs of Figures 4 and 5.

However, additional specific comments can be done concerning the comparison among the graphs. Projection scenario curves concerning minor demand fractions (d=0.2 and d=0.5) result slightly higher than the corresponding curves of the control scenario. Such a behaviour is more evident for the frequency (f=50%) and results congruent with the effects of climate change on rain characteristics (increased concentration and severity of rain events).

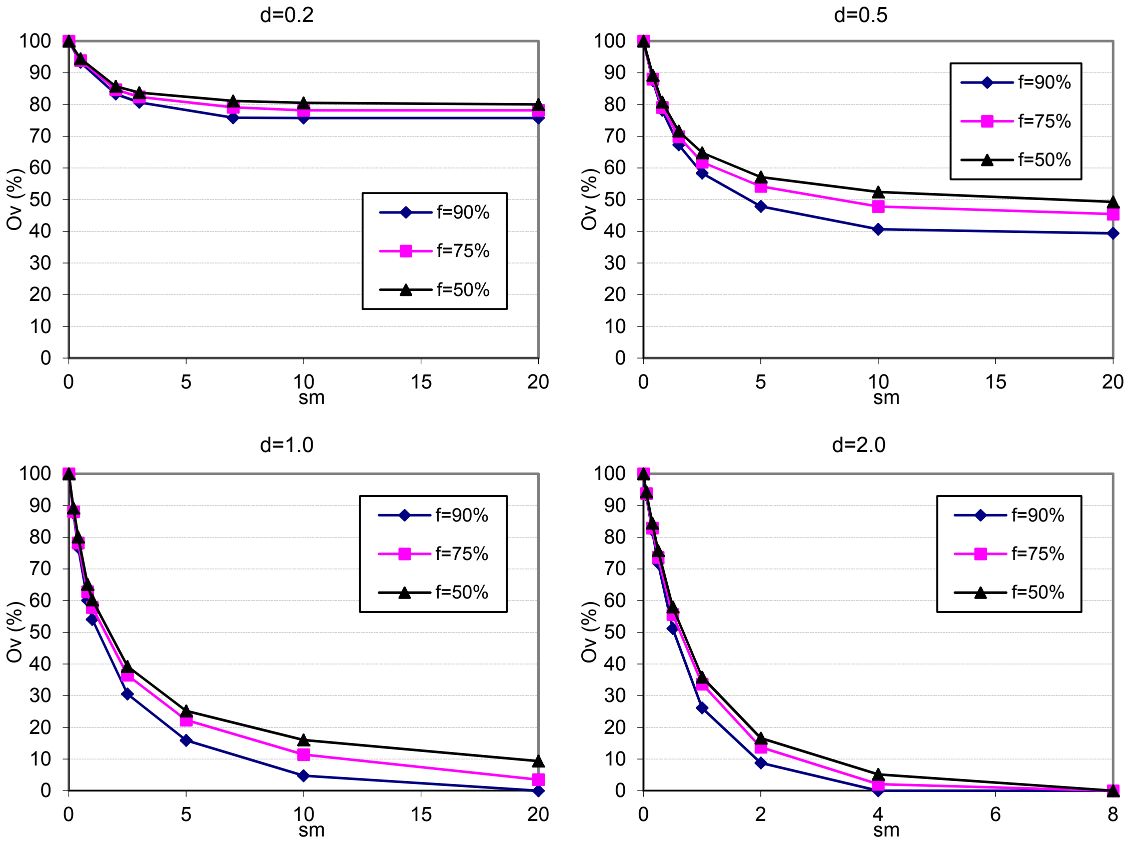

Figure 4. O_v values as function of *d* and s_m for the mid-term projection scenario (2013-2042)

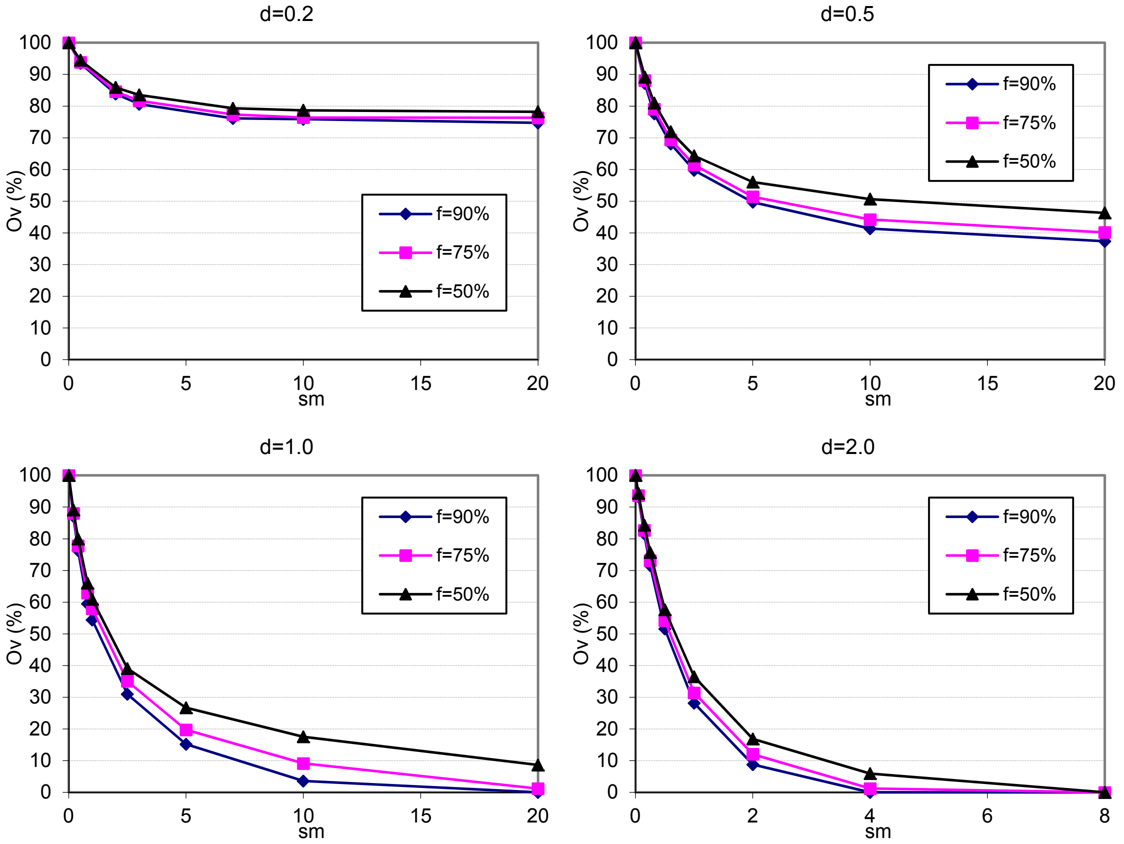

Figure 5. O_v values as function of *d* and s_m for the long-term projection scenario (2071-2100)

Globally, results confirm (at least at the daily scale) the DRWH system efficiency also under climate changing conditions and encourage further research developments at reduced sub-daily time resolution (i.e. at scale of rainfall event) to evaluate obtainable benefits in terms of runoff discharge reduction.

In any case, the obtained high overflow volumes for all the explored scenarios point out the possibility to extend rain water harvesting techniques to other domestic uses as well.

CONCLUSIONS

An analysis of the performance of rain water harvesting systems for domestic use was carried out in this paper. Since such systems are basically equipped with a storage tank to collect rainwater, the goal of this paper was to check the efficiency of the traditional DRWH systems to increase domestic water saving and also to reduce the inflow discharge to storm water sewer systems as an option to increase urban resilience to climate change impacts.

To this aim, a dimensionless methodology based on the results of water balance simulations at daily temporal scale was applied to determine both the obtainable water saving due to the a minor use of potable water and the reduction of water volumes discharged to the storm water sewer. In particular, the DRWH system performance was investigated as a function of two dimensionless parameters that allow to account for variable demand, storage, roof area and precipitation characteristics.

Also, different precipitation scenarios derived by regional climate models were considered as model input to assess the impact of climate change on the system performance.

The methodology was applied to daily rainfall data in Oslo (Norway). Three 30-years long rainfall series representative of historical and future precipitation scenarios were used to simulate the system behaviour by water balances at the daily time scale.

Results, presented by means of dimensionless graphs show, for all the considered scenarios, high water saving also for relatively small storage tanks and for high water demands with reduced marginal benefits as the tank size increases. The second important result is that the use of the storage tank can provide a significant reduction of water volume discharges to the storm water sewer.

A very similar performance of the system with the three different scenarios was obtained, confirming the efficiency of the system also under climate changing conditions. Obtained results have to be considered as preliminary and open the research discussion to test DRWH systems at more appropriate sub-daily time scales (i.e. at scale of rainfall event) to analyse benefits in reducing sewer peak flow rates and support municipalities to implement actions to cope with flooding and discharge to receiving water bodies.

LIST OF REFERENCES

Brodie, I. (2012). Stormwater harvesting and WSUD frequent flow management: A compatibility analysis. Water Science and Technology, Vol. 66, Issue 3, 612-619.

Burns, M.J., Fletcher, T.D., Hatt, B.E., Ladson, A.R. and Walsh, C.J. (2010). *Can allotment-scale rainwater harvesting manage urban flood risk and protect stream health?* Novatech 2010, 7th International Conference on Sustainable Techniques and Strategies in Urban Water Management, Lyon, France.

Burns, M.J., Fletcher, T.D., Duncan, H.P., Hatt, B.E., Ladson, A.R. and Walsh, C.J. (2012). *The stormwater retention performance of rainwater tanks at the landparcel scale.* 7th International Conference on Water Sensitive Urban Design, WSUD 2012, Melbourne.

Campisano, A. and Modica, C. (2012a). *Optimal sizing of storage tanks for domestic rainwater harvesting in Sicily*. Resour. Conserv. Recycl., 63, 9-16

Campisano, A. and Modica, C. (2012b). *Regional scale analysis for the design of storage tanks for domestic rainwater harvesting systems*. Water Science and Technology, 66(1), 1-8.

Coombes, P. J. and Barry, M. E. (2008). *The relative efficiency of water supply catchments and rainwater tanks in cities subject to variable climate and the potential for climate change*. Australian Journal of Water Resources Vol. 12, Issue 2, 85-100.

Eroksuz, E. and Rahman, A. (2010). *Rainwater tanks in multi-unit buildings: a case study for three Australian cities*. Resources, Conservation and Recycling, 54, 1449-1452.

Fewkes, A. and Butler, D. (2000). *Simulating the performance of rainwater collection systems using behavioural models?* Building Services Engineering Research and Technology, 21(2), 99-106.

Fewkes, A. (2000). *Modelling the performance of rainwater collection systems: towards a generalized approach*. Urban Water, 1(4), 323-333.

Fletcher, T.D., Mitchell, V.G., Deletic, A., Ladson, T.R. and Séven, A. (2007). *Is stormwater harvesting beneficial to urban waterway environmental flows?* Water Science and Technology, 55(4), 265-272.

Ghisi, E. and Ferreira, D.F. (2007) *Potential for potable water savings by using rainwater and greywater in a multi-story residential building in southern Brazil*. Building and Environment, 42(4), 2512-2522.

Guo, Y. and Baetz, B. (2007). *Sizing of rainwater storage units for Green Building applications*. Journal of Hydrologic Engineering, 12(2), 197-205.

Hafskjold L.S., Nie L.M., Bruaset S. (2012). *Vann i by – håndtering av overvann i bebygde områder (Water in city – handling stormwater in building areas)*. Sintef Building research guideline, No. 311.015.

Hanson, L.S., Vogel, R.M., Kirshen, P. and Shanahan, P. (2009). *Generalized storage-reliability-yield equations for rainwater harvesting systems*. In: Starrett S, editor. Proceedings of the world environmental and water resources congress 2009, Great Rivers.

Jenkins, D., Pearson, F., Moore, E., Sun, J.K. and Valentine, R. (1978). *Feasibility of rainwater collection systems in California*. In: Contribution no. 173. Californian Water Resources Centre, University of California.

Kjensli, P.O., Kielland, G., Langård N.O. (2009). Pluviometerdata fra norske kommuner (Pluviometer data from Norwegian municipalities). Technical memo. Met.no.

Lee, K.T., Lee, C.D., Yang, M.S. and Yu, C.C. (2000). *Probabilistic design of storage capacity for rainwater cistern systems.* Journal of Agricultural Engineering and Research, 77(3), 343-348.

Lindholm O., Endresen S. Thorolfsson S., Sægrov S. og Jakobsen G. and Aaby L. (2008). *Veiledning i overvannshåndtering og planlegging for klimaendringer (Guideline for climate adaptation for surface stormwater management*). Report 2008:162. Norwegian Water Association.

Matthew, P.J. and William, F.H. (2010). *Performance of rainwater harvesting systems in the southeastern United States.* Resour. Conserv. Recycl., 54, 623-629.

Mitchell, V.G., Deletic, A., Fletcher, T.D., Hatt, B.E. and McCarthy, D.T. (2007). *Achieving multiple benefits from stormwater harvesting.* Water Science and Technology, 55(4), 135-144.

Mwenge-Kahinda, J., Taigbenu, A. and Boroto, J. (2007). *Domestic rainwater harvesting to improve water supply in rural South Africa*. Phys. Chem. Earth, Parts A/B/C, 32(15-18), 1050-1057.

Nakicenovic, N. and Swart, R., (2000). Special report on Emission Scenarios, IPCC. Cambridge publication.

Oslo VAV (2011). *Overvannshåndtering – En veiledning for utbygger* (S*urface stormwater management– a guideline for development)*. Oslo Water and Sewage Works.

Palla, A., Gnecco, I. and Lanza, L.G. (2011). *Non-dimensional design parameters and performance assessment of rainwater harvesting systems.* Journal of Hydrology, Vol. 401, Issue 1-2, 65-76.

Petrucci, G., Deroubaix, J.F., de Gouvello, B., Deutsch, J.C., Bompard, P. and Tassin, B. (2012). *Rainwater harvesting to control stormwater runoff in suburban areas. An experimental case-study*. Urban Water Journal, 9(1), 45-55.

Skaugen, T.E. (2004). *Refinement of dynamically downscaled precipitation and temperature scenarios.* Norwegian Meteorological Institute report 2004:15.

Tsai, Y.L. and Chiu, Y.R. (2012). *Urban storm runoff utilization strategy and volume analysis in multi-purpose rainwater detention-retention systems*. Advances in Water Science, Vol. 23, Issue 3, 341-345.

Villarreal, E.L. and Dixon, A. (2005). *Analysis of a rainwater collection system for domestic water supply in Ringdansen, Norrköping, Sweden*. Building and Environment, 40(9),1174-84.

Zhang, X., Hu, M., Chen, G. and Xu, Y. (2012). *Urban Rainwater Utilization and its Role in Mitigating Urban Waterlogging Problems - A Case Study in Nanjing, China*. Water Resour Manage, 26, 3757-3766.